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Climate Policy Induced Investments in Developing Countries

The Implications of Investment Risks

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Nontechnical Summary

This paper investigates the implications of investment risks in climate policy induced investments in developing countries. Emission crediting provides market-based incentives to invest in climate-friendly (i.e. emission mitigation) projects since emission reductions can be sold on international permit markets, thus recovering higher initial investment costs. We provide a quantitative assessment of how investment risks to project-based emission crediting between industrialized countries and developing countries affect the magnitude and distribution of economic gains from joint implementation of emission abatement. Based on a multi-region partial equilibrium model of marginal carbon abatement cost curves, we find that project-based emission crediting in developing countries drastically reduce the overall costs for industrialized countries that aim at substantial cutbacks of their business-as-usual emission levels. At the same time, it provides considerable income to developing countries with larger low-cost abatement options. The incorporation of country-specific investment risks induces only small changes to the magnitude and distribution of benefits from project-based emission trading vis-à-vis a situation where investment risks are absent. Only if investors are highly risk-averse will the differences in risk across developing countries become more pronounced and induce a non-negligible shift in comparative advantage from high-risk developing countries to low-risk developing countries. Although the total amount of emission credits across all developing countries will distinctly shrink for this case (i.e. domestic abatement shares in industrialized countries increase), the low-risk developing countries may attract higher project volumes at the expense of high-risk countries and may also benefit from higher effective prices per emission credit compared to a simulation without risk. The opposite applies to high-risk countries. The welfare implications of risk incorporation for industrialized countries are unambiguously negative. Sensitivity analysis with respect to the magnitude of investment risks highlights the relevance of risk aspects. When investors go for high safety of returns and perceive substantial differences in project-based risks across countries, only very cheap projects in high-risk developing countries will be realized, and the associated benefits to high-risk countries may fall close to zero, while low-risk developing countries will fare even better. Our results are supported by empirical evidence on regional imbalances of activities implemented jointly under the pilot phase of the Kyoto Protocol.

Climate Policy Induced Investments in Developing Countries: The Implications of Investment Risks

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Abstract: International climate policy has assigned the leading role in emissions abatement to the industrialized countries while developing countries remain uncommitted to binding emission reduction targets. However, cooperation between the industrialized and the developing world through joint implementation of emission abatement promises substantial economic gains to both parties. In this context, the policy debate on joint implementation has addressed the question of how investment risks to project-based emission crediting between industrialized countries and developing countries affect the magnitude and distribution of such gains. In our quantitative analysis, we find that the incorporation of country-specific investment risks induces rather small changes vis-à-vis a situation where investment risks are neglected. Only if investors go for high safety of returns is there a distinct decline in the overall volume of emission crediting and the associated total economic benefits. While the welfare effects of risk incorporation for industrialized countries are unequivocally negative, the implications across developing countries are ambiguous. Whereas low-risk developing countries attract higher project volumes and benefit from higher effective prices per emission credit compared to a reference scenario without risk, the opposite applies to high-risk countries. Sensitivity analysis with respect to higher risk estimates show that shifts in the comparative advantage of emission abatement against high-risk countries may become dramatic as only very low-cost mitigation projects will be realized, driving down the country's benefits from emission crediting to the advantage of low-risk developing countries. This result is supported by empirical evidence on regional imbalances of activities implemented jointly under the pilot phase of the Kyoto Protocol.

JEL classification: D81, O16, Q25
Keywords: investment risks; international climate policy

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1. Introduction

International climate policy has assigned the leading role in emissions abatement to the industrialized countries who have assumed historical responsibility for the greenhouse gas (GHG) problem. Developing countries remain uncommitted to GHG abatement. They argue that they carry only minor historical responsibility for the increase of global GHG concentrations in the atmosphere. Before decisions are made that could hinder their economic growth through restrictions on fossil fuel use, the industrialized countries should first undertake substantial emission reduction.

This argument, however, is moot. Cooperation between the industrialized and the developing world through joint implementation of GHG emission abatement promises substantial economic gains to both parties. As long as the costs for GHG mitigation that industrialized countries have committed to are lower in developing countries, it makes economic sense that developing countries undertake abatement projects in return for funds from industrialized countries which receive emission credits counting to their domestic emission targets. This basic idea of cost-effectiveness led to the clean development mechanism (CDM) under the Kyoto Protocol accommodating project-based emission reductions in developing countries to exploit the potential for low-cost abatement.

Emission crediting provides market-based incentives to invest in climate-friendly (i.e. emission mitigation) projects since emission reductions can be sold on international permit markets, thus recovering higher initial investment costs. With emission crediting, developing countries could attract larger amounts of foreign direct investment (FDI), which is the dominant long-term resource flow to developing countries with a net volume of 185 bn. USD in 1999 (World Bank, 2001). FDI generates technology spillovers, contributes to international trade integration, and fosters human capital formation, all of which accelerates economic growth as the most potent tool for poverty alleviation in developing countries. The importance of FDI as an economic development device is highlighted by the fact that the private flow of FDI overshadows official development assistance (ODA) by a wide margin.[1]

Many policy makers, hence, consider project-based emission reductions as an important instrument to promote sustainable development with respect to improved environmental quality as well as better economic performance of developing countries. Yet, there are

[1] Official development assistance amounted to only around 41 bn. USD in 1999 (OECD, 2002).

concerns that the potential benefits of project-based abatement measures may be substantially reduced by risk concerns of investors associated with abatement projects in developing countries. In addition, the uneven distribution of investment risks and abatement possibilities could produce a (politically undesired) shift in comparative advantage of emission abatement stacked against least-developed countries that typically bear high investment risks and dispose of rather limited abatement possibilities due to low emission levels (Wirl et al., 1998). Climate-friendly investment would then mirror the uneven spread of conventional FDI to developing countries.

The objective of this paper is to provide quantitative insights into the relative importance of risk preferences to project-based emission crediting with developing countries. To what extent do risk considerations reduce the potential for cost savings to industrialized countries? What are the implications of risk for the magnitude and distribution of benefits from project-based emission trading among developing countries? So far, quantitative estimates in the literature on the economic impacts of comprehensive emission trading across countries – the so-called 'where'-flexibility - have been abstracting from risk considerations (see overviews in Weyant, 1999; IPCC, 2001). Based on simulations with a simple partial equilibrium model of emission trade, our key insights can be summarized as follows:

(i) Project-based emission crediting in developing countries drastically reduce the overall costs for industrialized countries that aim at substantial cutbacks of their business-as-usual GHG emission levels. At the same time, it provides considerable income to developing countries with larger low-cost abatement options.

(ii) Incorporation of country-specific investment risks induces only small changes to the magnitude and distribution of benefits from project-based emission trading vis-à-vis a situation where investment risks are absent. Only if investors are highly risk-averse will the differences in risk across developing countries become more pronounced and induce a non-negligible shift in comparative advantage from high-risk developing countries to low-risk developing countries. Although the total amount of emission credits across all developing countries will distinctly shrink for this case (i.e. domestic abatement shares in industrialized countries increase), the low-risk developing countries may attract higher project volumes at the expense of high-risk countries and may also benefit from higher effective prices per emission credit compared to a simulation without risk. The opposite applies to high-risk countries. The welfare implications of risk incorporation for industrialized countries are unambiguously negative.

(iii) Sensitivity analysis with respect to the magnitude of investment risks highlights the relevance of risk aspects. When investors go for high safety of returns and perceive substantial differences in project-based risks across countries, only very cheap projects in high-risk developing countries will be realized, and the associated benefits to high-risk countries may fall close to zero, while low-risk developing countries will fare even better.

The remainder of this paper is organized as follows. Section 2 describes alternative approaches to capture investment risks. Section 3 gives a brief non-technical summary of the partial equilibrium model underlying our simulation analysis, illustrates the potential implications of risk accounting, and describes empirical estimation as well as model implementation of investment risks. Section 4 discusses policy scenarios and results. Section 5 presents a sensitivity analysis. Section 6 concludes.

2. Investment Risks in Project-Based Emission Crediting

The clean development mechanism can be characterized as a baseline-and-credit regime under which emission credits for industrialized countries relate to emissions reductions achieved by eligible GHG mitigation projects in developing countries (Sorrell and Skea, 1999; Janssen, 2000). Emission reductions are calculated by comparing the actual emissions of a project with the emissions that would have occurred in the absence of the relevant project, i.e. the reference scenario or baseline. CDM projects involve cross-border investments by industrialized countries in order to generate emission credits for subsequent sale on international credit markets or for transfer emission credits (Grubb et al., 1999). Private investors treat abatement projects in the same manner as ‘conventional’ projects.[2] The investor provides debt and equity financing of the mitigation project in exchange for the claims on the project and the net cash flow it produces (financial return). Emission credits from emission reduction contribute to the net cash flow. Hence, the sale of permits from

[2] Investment decisions made by private firms are especially climate-relevant in the building, industrial, transport, and energy sectors. One of the leading infrastructure sectors in attracting private investment is electricity generation, with total private investments of 131 bn. USD between the years 1990 and 1997 (Zhang and Maruyama, 2001).

climate-friendly projects makes it possible to recover higher-investment costs of mitigation projects vis-a-vis ‘conventional’ projects.

The return on the investment is influenced by several factors that can not be controlled by the investor. Drawing on the literature on foreign direct investment, Janssen (2002) distinguishes three main categories of risk that can affect the performance of project-based emissions crediting: (i) *technological risks* that are tied to the process of production and refer to uncertain output quantities; (ii) *economic risks* that refer to uncertain input and output prices; and (iii) *political risks* that arise from uncertainty about property rights on the assets of the revenue streams and involve tax changes or, as the most drastic example, expropriation. Potential investors interested in participating in emissions reduction projects taking place in developing countries may hesitate because of these investment risks. There are high barriers for finding appropriate financing especially for ‘typical’ projects that are small or medium-sized, located in a developing country, and dependent on new or innovative technologies or processes. Further, market prices for emission reductions from climate-friendly investment are uncertain. Finally, risk factors are determined by country specific considerations. Investors will seek host developing countries that are politically and economically stable. In addition, these countries should have a sound institutional framework, a reliable public infrastructure (energy, water, transport) and the capacity to receive and support international investments.[3]

Among the developing countries, especially African countries (excluding South Africa) failed to attract inward FDI in recent decades, even though gross returns on investment have been very high. The reasons are the significant risks of capital losses, most importantly macroeconomic instability, loss of assets due to the non-enforceability of contract, and physical destruction caused by armed conflicts (OECD, 2002). Risk diversification by investors may be achieved via investments in different countries, technologies and project types. For our analysis, we assume that the risks in emission crediting are predominantly country-specific, i.e. the variations in the profits of single projects are mainly due to the economic or political conditions in the project’s host countries.

[3] Instead of building their own diversified portfolio of projects, investors could invest indirectly in a portfolio of projects through investment vehicles offered by financial institutions. One of the few examples for carbon funds is the World Bank’s Prototype Carbon Fund (PCF). Investors in the PCF are private companies such as Gas de France, Deutsche Bank and Mitsubishi, as well as the governments of Canada, Finland, The Netherlands, Norway and Sweden.

Investors invest in 'conventional' projects that yield a return greater than the minimum acceptable hurdle rate, i.e. the return on a risk-free investment plus a risk premium. In contrast, investors will undertake investments induced by domestic emission limitations as long as their perceived return is positive, i.e. the price received for the emission credit sold on international permit markets is higher than the associated (risk adjusted) marginal abatement cost in the project's host country. Below, we first provide the optimal investment rule in the absence of investment risks (Section 2.1). We then present different approaches to how risk characteristics can be incorporated, i.e. affect the optimal investment rule (Section 2.2).

2.1 Emission Crediting in the Absence of Investment Risks

Investors will engage in project-based emission crediting and choose a single risk-free project in country *i* if

$$Y_i = \frac{p - c_i'}{c_i'} > 0 \tag{1}$$

where Y_i is the profit per dollar invested in one unit of emission credits, p is the price received for the emission credit and $c_i' = c_i'(q_i)$ are the marginal costs of financing unit abatement in country *i*, which depends on the quantity of abatement undertaken q_i.

2.2 Emission Crediting with Investment Risks

Omission of risk aspects may significantly overestimate the potential benefits from emission crediting. Obviously, investors will demand a higher rate of return, i.e. a risk premium, for risky projects, compared to risk-free options. We capture country-specific risks of emission crediting through a random variable τ_i that quantifies the fraction of the generated credits that drop out. Accounting for country-specific risks, the return from the investment in a single project in country *i* is given by:

$$X_i = \frac{(1-\tau_i)\cdot p - c_i'}{c_i'} \tag{2}$$

where X_i is a random variable, since τ_i is random, with expected monetary value EX_i, variance $V(X_i)$ and standard deviation σ_{X_i}.[4]

2.2.1 Mean-value criterion (μ)

If investors are *risk-neutral* they aim at maximizing their return from abatement investments, disregarding the associated risk levels. Accordingly, they judge risky projects solely by their expected return. The decision rule for abatement investments in a single project becomes

$$EX_i > 0. \tag{3}$$

However, investors in unique choice situations usually not only care about the expected return of the investment project but also about the return volatility, which indicates the investment risk. The overwhelming majority of financial models assumes investors to be risk averse, i.e. they have a cautious attitude in the context of reasonable decision making.

The risk aspect of the decision problem does not vanish if we take into account the possibility that project-based emission crediting in country *i* comes about by summing up the incomes of various non-rival subprojects that are carried out at the same time by the investors, i.e. the private companies in industrialized countries or the industrialized countries themselves.[5] However, the bundling of projects in large host countries could significantly reduce the risks of CDM investments and bring them down to the country-specific risks. To

[4] This holds independent of the responsibility for non-compliance, i.e. under seller beware or buyer beware liability.

[5] The Law of Large Numbers implies that in the case of stochastic independence of the single projects, the average gain converges stochastically towards the expected gain from the single performance as the number of performances approaches infinity. Following this criterion, the choice of a single project may be based on the mean-value criterion in the case of multiple risks. However, the conditions of the Law of Large Numbers are not satisfied in our context, since the number of projects is not sufficiently large and – most importantly - the different projects are not stochastic independent. The part of the variance that is caused by factors that are common to all single projects can not be eliminated by increasing the number of contracts pooled (Sinn 1989). While technological risks of the individual projects might be considered as stochastically independent, economic and political risks are mostly country specific. The netting-out of dispersions thus does not take place for the country risks.

this end, carbon funds not only serve as vehicles for channeling investments, but also as risk reduction devices (Janssen, 2002). The risk premia for emission projects may hence be based on risk premia for investment projects in these countries, which we capture through the use of interest rate spreads (see Section 2.4).

There are different approaches to manage and control risk. In our empirical assessment we adapt two of them to adjust the investment decision rule and allow for the cost of risk-bearing: the mean-variance (μ-σ) approach which dominates portfolio theory (Markowitz, 1952)[6] and the value at risk (VaR) approach which is a method widely used by banks and financial firms (Jorion, 2001).

2.2.2 Mean-variance decision criterion (μ,σ)

Under the mean-variance criteria the investment rule becomes

$$EX_i - \frac{\alpha}{2} \cdot V\left(X_i\right) > 0. \qquad (4)$$

The mean-variance decision function is consistent with the expected utility principle if the investor's utility function *u* is of the constant absolute risk aversion (CARA) type and defined over normally distributed monetary consequences X_i. In this case, it is equal to the cash equivalent of the project return $EX_i - \pi_i$, where π describes the risk premium, i.e. the maximum part of the expected return that the investor is prepared to forfeit in order to avoid the risk associated with the investment.[7]

Empirical findings on risk attitudes are rare and depend to a large extent on the specific method used. Therefore, we study a wide range of values for α, namely $\alpha \in [0;25]$. This

[6] Portfolio diversification of carbon abatement options as proposed by Springer (2002) requires the assumption of constant marginal abatement costs to derive expected returns from marginal abatement curves. Since this assumption does not seem plausible, we do not follow the portfolio approach.

[7] For small risks, the risk premium can be approximated by $\pi_i = 1/2 \cdot r\left(EX_i\right) \cdot V\left(X_i\right)$, where $r\left(x_i\right) = -u''\left(x_i\right)/u'\left(x_i\right)$ $\forall x_i$ is the Arrow-Pratt coefficient of (local) absolute risk aversion (ARA) (Pratt 1964, Arrow 1965). If the decision maker's utility function has the form $u\left(x_i\right) \sim -e^{-\alpha \cdot x_i}$ (negative-exponential), where ~ denotes equality except for change of utility scale, then the decision maker has constant absolute risk aversion (CARA) with $r\left(x_i\right) = \alpha$, i.e. absolute risk aversion is not affected by the level of x_i (Pratt et al. 1995).

range is consistent with studies in financial economics which assume investors with mean-variance preferences and absolute risk aversion (Aït-Sahalia and Brandt, 2001; Alexander and Baptista, 2002). A slightly risk-averse agent may be characterized through $\alpha = 2$, a moderate risk-averse agent through $\alpha = (5, 10)$, and a highly risk-averse agent through $\alpha = 25$.

2.2.3 Value at Risk decision criterion (VaR)

Another method to analyze the risk-return trade-off in investments is the Value at Risk (VaR) approach. The concept of VaR as a measure of risk was first proposed by Baumol (1963) and is associated to 'safety first models' initially analyzed by Telser (1955). More recently, it became popular in financial economics. For example, the Basel Capital Accord requires internationally active banks to determine the minimum regulatory capital in support of their trading portfolios by using the VaR approach (Santos, 2001).

The VaR indicates the greatest potential loss of a position (or a portfolio) with a stochastic rate of return X_i one expects to suffer over a given time interval within a given confidence level *t* (Jorion, 2001). VaR is usually defined as the dollar loss relative to the mean:

$$VaR_i = EX_i - X_i^*, \tag{5}$$

where X_i^* is the lowest return at the given confidence level *t* called the sample quantile of the distribution.[8] The decision criterion under the VaR approach is given by:

$$VaR_i = EX_i - \beta \cdot \sigma_{X_i} > 0., \tag{6}$$

where in the case of a normal distribution of the return β is such that $\Phi(-\beta) = (1-t)$ with $\Phi(.)$ being the standard normal cumulative distribution function. Without any distributional

[8] The probability of a lower value than X_i^* is therefore $(1-t) = P\left(x_i < X_i^*\right) = \int_{-\infty}^{X_i^*} f_{X_i}(x_i)\,dx_i$, with f_{X_i} being the probability density function of the investment return X_i. The computation of the VaR simplifies considerably if the distribution of the return is assumed to be normal. In this case, the problem of finding a VaR is equivalent to finding the deviate β such that the area under the standard normal probability density function to the left of it is (1 - *t*).

assumption imposed on the investment return, a useful lower bound on the VaR is provided by Chebyshev's inequality which yields $t = 1-(1/\beta)^2$.[9] For example, the Chebyshev lower bound on the VaR for a confidence level of t = 0.90 (0.95) is $EX_i - 3.16 \cdot \sigma_{X_i}$ $\left(EX_i - 4.47 \cdot \sigma_{X_i}\right)$, whereas under normality the VaR is $EX_i - 1.28 \cdot \sigma_{X_i}$ $\left(EX_i - 1.65 \cdot \sigma_{X_i}\right)$ (Alexander and Baptista, 2002).

3. Analytical Framework and Parameterization

Below, we first provide a description of the partial equilibrium model of permit trading with investment risk and its parameterization (Section 3.1). Section 3.2 illustrates the intuition how investment risks change the optimal pattern of abatement across regions. Finally, in Section 3.3 we describe how investment risks of CDM projects can be estimated using interest-rate spreads between countries and how investment risks are implemented in our model.

3.1 A Model of Permit Trade with Investment Risks

To quantify the economy-wide implications of risk consideration in multilateral emission crediting, we make use of a partial equilibrium model for permit trade (see Böhringer and Löschel, forthcoming; Löschel and Zhang, 2002). The analysis below is based on marginal abatement cost curves for 13 regions. These curves capture the marginal cost of reducing carbon emissions by different amounts within an economy. Marginal costs of abatement may vary considerably across countries due to differences in carbon intensity, initial energy price levels, and the ease of carbon substitution possibilities.

Each country i's compliance costs to some exogenous target level t_i equal the sum of abatement costs, resource costs from investment failure, and the costs of buying carbon permits. The single country's optimization problem can be stated as:

$$\min_{q_i} \; c_i\left(q_i\right) + r_i\left(q_i\right) + p \cdot \left(\overline{e_i} - q_i - t_i\right) \qquad (7)$$

[9] The Chebyshev inequality is $P\left\{\left|X_i - EX_i\right| \geq \left(\beta \cdot \sigma_{X_i}\right)\right\} \leq \left[\sigma_{X_i} / \left(\beta \cdot \sigma_{X_i}\right)\right]^2$.

s.t. $q_i \geq 0$

where q_i are the emission reductions, c_i denotes the abatement cost function for reducing carbon emissions, r_i quantifies the costs from investment risks (r_i = 0 for industrialized countries), $\overline{e_i}$ stands for the business-as-usual emissions, t_i denotes the emission target level (i.e. a country's initial endowment of permits), and p is the permit price taken as exogenous. The quantity of permits traded is given by $\overline{e_i} - q_i - t_i$.

The first-order condition for the cost minimization problem is given by:

$$c_i^{'}(q_i) + r_i^{'}(q_i) = p \tag{8}$$

In the optimum, countries abate emissions up to a level where their marginal abatement costs plus marginal investment risk are equal to the permit price. The marginal abatement costs experienced by industrialized countries that demand emission permits from project-based abatement, exceed the marginal abatement costs experienced by developing countries by the amount of the marginal costs from investment risk. Total costs of reducing emissions to the overall target level are minimized, since all opportunities for exploiting cost differences in abatement across countries are taken.

The empirical specification of the costs from investment risks and their concrete implementation for different risk attitudes is described in Section 3.3. For the regional marginal abatement costs curves, we adopt a constant elasticity function of the form:

$$c_i^{'}(q_i) = \chi_i \cdot q_i^{\delta_i} \tag{9}$$

In order to determine the coefficients χ and δ, we employ a least-square procedure based on a sufficiently large number of discrete observations for marginal abatement costs and the associated emission reduction in each region. These values stem from the world energy system model POLES (Criqui et. al., 1996), which embodies a detailed bottom-up description of regional energy markets and world-energy trade. Table 1 summarizes the countries and regions in the model, their baseline emissions in the year 2010[10] and the least-square estimates for the coefficients of marginal abatement cost curves.

Table 1 Model dimensions and data

Countries and Regions		Emissions [a]	FDI [b]	χ	δ
Industrialized World					
AUN	Australia and New Zealand	130		0.675	1.442
CAN	Canada	165		1.567	1.379
CEA	Central European Associates	209		0.316	1.388
EUR	Europe (EU15 and EFTA)	1,040		0.114	1.369
FSU	Former Soviet Union (incl. Ukraine)	593		0.046	1.482
JPN	Japan	330		0.718	1.338
USA	United States	1,809		0.020	1.427
Developing World					
AFR	Africa	294	7,949	0.366	1.231
ASI	Other Asia	655	18,189	0.295	1.231
CHN	China	1,131	38,753	0.022	1.280
IND	India	351	2,169	0.452	1.201
MPC	Mexico and OPEC	531	1,461	0.546	1.269
MSA	Middle and South America	394	3,893	0.299	1.456

[a] Baseline emissions in MtC in the year 2010 based on DOE (2001) reference case.
[b] Inward FDI flows to developing countries in millions USD in the year 1999 (World Bank, 2001).

3.2 Economic Effects of Investment Risks

Figure 1 illustrates the central effects of investment risks on the emission credit market in a simple three-country partial equilibrium framework. The effects are similar to those of transaction costs (Stavins, 1995).[11] There is some industrialized country that faces total abatement requirement of *T*. It can fulfill its obligations by either domestic abatement or by investments in abatement projects abroad. The demand curve *D* for emission credits from abroad is determined by the marginal abatement cost curve of the industrialized country. On the other hand, there are two (unrestricted) project host countries with marginal abatement

[10] In our comparative-static simulations we employ 2010 as the target year for emission reduction commitments by industrialized countries. The marginal abatement cost curves generated by the POLES model are also based on bottom-up data for 2010.

[11] Transaction costs in pollution allowance trading may arise from a variety of activities associated with market exchange, e.g. search and information acquisition, bargaining over prices, and negotiation, monitoring and enforcement of contracts (Stavins, 1995). In our analysis we abstract from such transaction costs. Note that investment risks are sometimes considered as transaction costs in a broader use that covers any policy-related costs other than the conventionally measured economic adjustment responses (Krutilla, 1999).

cost functions $c_i^{'}$ (i = 1,2) that yield the total supply S of emissions generated through projects.

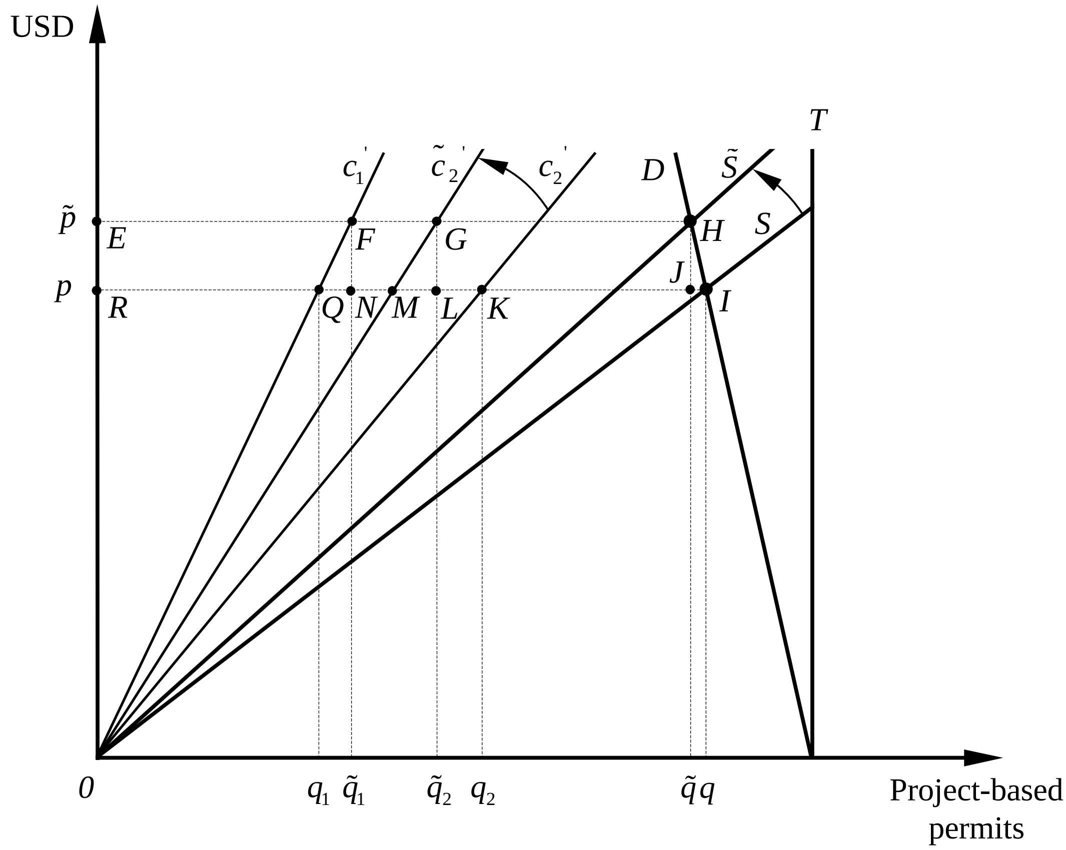
In the absence of investment risks, the industrialized country demands emission credits generated through projects as long as the price for the credits is below its marginal abatement costs. In the market equilibrium, marginal abatement costs are equalized at price p across domestic abatement activities undertaken in the industrialized country and projects abroad that are hosted in the developing countries. The total amount of emission credits generated by projects abroad is $q = q_1 + q_2$, with q_1 representing projects undertaken in country 1 and q_2 projects undertaken in country 2, respectively. In the cost-effective solution, the industrialized country purchases credits q and abates domestically $T – q$.

Investment risks are real resource costs and lead to a different equilibrium than in the absence of investment risks, where marginal abatement costs are equalized across all regions in equilibrium. It is still cost effective, but involves greater aggregate compliance costs than the cost-effective solution in the absence of investment risks. If investment risks associated with abatement projects are taken into account as described in (3), the investment decision is governed by the risk-adjusted marginal abatement costs $\tilde{c}_i^{'} = \left(1/\left(1-\tau_i\right)\right)\cdot c_i^{'}$, which is the effective permit supply curve facing permit demanders. We assume that only investments in country 2 are risky and induce a shift of its effective supply curve in the investor's perspective from $c_2^{'}$ to $\tilde{c}_2^{'}$. Rather than equilibrating marginal abatement costs as is done in the absence of investment risk, the sum of marginal abatement costs and marginal investment risks are equalized. Investment risks raise the costs for the participants in permit trade and thereby unambiguously decrease the volume of permit trading. The new market equilibrium with investment risks is characterized by a higher credit price $\tilde{p}$ which decreases the purchase of emission credits (i.e. the industrialized country's abatement investments) from abroad to $\tilde{q}$ and increases domestic abatement of the industrialized country to $T - \tilde{q}$. Hence, investment risks abroad shift the comparative advantage to domestic actions. In addition, the amount of investment projects in the more risky country 2 decreases $\left(q_2 - \tilde{q}_2\right)$ while more projects are undertaken in the less risky country 1 $\left(\tilde{q}_1 - q_1\right)$ reflecting a shift in comparative advantage towards the less risky host country.

Overall, the potential efficiency gains from permit trade are reduced under risk accounting vis-à-vis a situation where risk is neglected. The true costs of control are higher with investment risks. This stems partly from the resource costs from investment risks and partly from the suppression of permit trade that has been mutually beneficial in the absence of investment risks. The burden from investment risk considerations is unevenly shared between permit demanders and high- and low-risk permit suppliers. The benefits from emission crediting for the industrialized countries and higher risk host countries decrease, whereas low-risk host countries may gain compared to the 'no-risk' situation. Industrialized countries are unambiguously worse off compared to a situation characterized by the absence of investment risks. The industrialized countries have to do more abatement domestically and pay higher prices on the permit market. The increase in compliance costs for the industrialized country in Figure 1 equals the area *EHIR*. It is composed of higher abatement costs (*HIJ*) and higher costs of permit imports (*EHJR*) from both no-risk country 1 (*EFNR*) and high-risk country 2 (*EGLR*). The no-risk host country 2 is unambiguously better off since it enjoys higher profits from permit trade (*EFQR*). The effects of investment risks on risky countries such as country 2 are ambiguous. On the one hand, they profit from higher permit prices (*EGMR*), on the other, hand the trading volume is reduced and they have to bear the resource costs from investment risks (*MK0*). As with the tax incidence, the overall effects depend on the elasiticities of the marginal abatement cost functions, which determine the share of the resource costs from emission crediting that can be passed on to industrialized countries as an increase in the price of permits. In general, the burden from investment risks falls more heavily on the countries with relatively steep marginal abatement cost curves.

Figure 1 illustrates the important point that industrialized countries ignoring investment risks of project-based emissions crediting overestimate the potential cost savings from credit trading, i.e. the desirable level of investment abroad, and misallocate investments across project-host countries with different risk levels. High-risk countries receive less investments than in the absence of investment risks, low-risk countries receive more investments.

Figure 1 Effects of investment risks



3.3 Estimation of Investment Risks and Implementation

The default risk premium, i.e. the higher rate of return investors will demand for risky projects compared to risk-free options, reflects the market's assessment of country and project risk. To estimate risk premia at both the country and project level, different techniques may be applied, e.g. econometric analysis of past projects (Dailami and Leipziger, 1999). Saini and Bates (1984) give an overview over various methods for the analysis of country-specific investment risk, which is the predominant risk category in mitigation projects. They hence provide a lower bound estimate of the risk involved in project investment. One indicator of country risks are sovereign debt ratings determined by both political factors (degree of democratization, integration with world economy, security risks) and economic factors (per capita GDP, growth prospect, public debt, price stability, balance of payment flexibility, external debts). These are provided by international rating agencies, such as Standard & Poors

Corporation and Moody's Investors Service.[12] Another established approach is the use of the interest rate spread. Several studies have shown that interest rate spreads between bonds carry substantial information for determining country risk (e.g. Edwards, 1986).

For our analysis, we employ bond yield spreads between long-term government bonds of the developing country *i* where the emission abatement project is located (risky country) and the US (as a risk-free reference country) to determine the developing country's risk premium τ_i. The calculation of country-specific investment risks is based on data from the International Monetary Fund's International Financial Statistics (IFS) (IMF, 2000). IFS provides time series data for key economic indicators of most IMF members (over 200 countries), such as a country's exchange rates, international liquidity, money and banking accounts, interest rates, production indices, prices, international transactions, government accounts, and national accounts, as well as commodity and trade statistics. The data on long-term government bond yields that we use to measure the investment risk is given in monthly steps from 1981 to 2001. In order to aggregate the single country level data to the regions of our simulation model (see Table 1), the long-term government bond yields are weighted with the country's share in direct investments of the associated region. The descriptive statistics of the country-specific risk premiums for the model regions with a mapping of IFS countries are given in Table 2. The expected risk premium $E\tau_i$ and the variance $V(\tau_i)$ are approximated by the sample mean and variance, respectively. Using this information, the expected return of investment projects in country *i*, its variance and standard deviation are given by: $EX_i = \left[(1-E\tau_i)\cdot p - c_i'\right] / c_i'$, $V(X_i) = \left(p/c_i'\right)^2 \cdot V(\tau_i)$, and $\sigma_{X_i} = \left(p/c_i'\right)\cdot\sigma_{\tau_i}$, where σ_{τ_i} denotes the standard deviation of the yield spread.

For example, if the expected value of the yield spread of the country *i* (where the project is undertaken) amounts to τ_i = 0.1, the investing industrialized country obtains on average only 90 percent of the emission credits from projects carried out in this country due to the investment risk. The expected return for the marginal investment project that delivers one emission credit at price c_i' = 40 USD and saves abatement costs of *p* = 50 USD in the

[12] Moody's long-term bond rating classifications range from Aaa (the best) to C (the worst). The default spreads for different countries associated with the bond ratings are e.g. 4.5 % for Brazil (B1), 0.95 % for China (A3), 7.5 % for Cuba (Caa1), 3% for India (Ba2), and 6.5 % for Indonesia (B3) (Damodaran, 1999).

industrialized country is EX_i = 0.19 with investment risk and Y_i = 0.25 without investment risk considerations. If the variance of the country-specific risk premium is assumed to be $V(\tau_i)$ = 0.01 (i.e. the standard deviation amounts to σ_{τ_i} = 0.10) the variance of the project return is $V(X_i)$ = 0.016, and the standard deviation is σ_{X_i} = 0.125.

We implement the different attitudes towards risk as described in Section 2.2 through explicit constraints on the ratio of the price received for the emission credit over the marginal costs of the project generating the credit unit in country *i*, i.e. p/c_i'. For the different risk attitudes, an investment in emission reduction projects is profitable as long as:

$$\frac{p}{c_i'} \geq \frac{1}{1-E\tau_i} \qquad (\mu) \qquad (10)$$

$$\frac{p}{c_i'} \geq \frac{1-E\tau_i-\sqrt{(1-E\tau_i)^2-2\cdot\alpha\cdot V(\tau_i)}}{\alpha\cdot V(\tau_i)} \qquad (\mu,\sigma) \qquad (11)$$

$$\frac{p}{c_i'} \geq \frac{1}{1-E\tau_i-\beta\cdot\sigma_{\tau_i}} \qquad (VaR) \qquad (12)$$

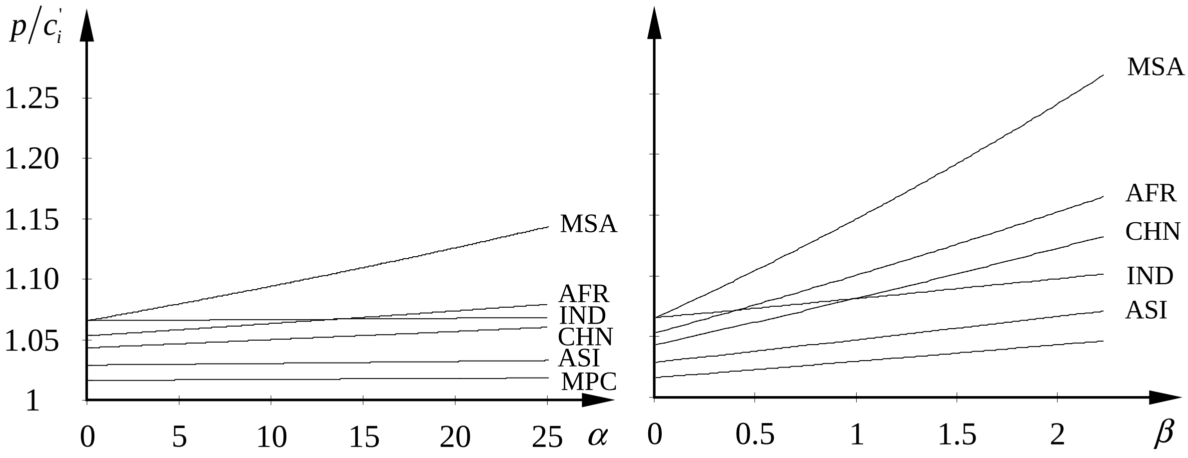
Figure 2 illustrates the effect of changes in the risk aversion parameters α under (μ,σ) preferences and β under VaR preferences on the price-cost-ratio of emission crediting between the industrialized world and the developing regions represented in our model. The ratio under μ and VaR preferences coincide for certain values of α and β, e.g. the ratio for developing region MSA is 1.1 for α = 11.9 and β = 0.44 (t = 0.67). In case $\alpha = \beta = 0$ the investment rule for μ and VAR preferences coincide with equation (10). The price-cost ratio increases faster in α and β for countries with relatively high variance of returns, such as AFR, MSA or CHN, while the ratio increases only slightly for countries with relatively low variance, i.e. ASI, MPC, IND. The basic message of Figure 2 is that risk aversion can substantially exacerbate the differences in attractiveness of investment projects across host countries. The increasing perceived costs associated with investment risks enlarge the departure of the equilibrium with investment risk from the equilibrium in the absence of investment risk and drive up the total aggregate compliance costs.

Table 2 *Descriptive statistics of bond yield spreads* τ

Regions	IFS countries	Obs.	Mean	Median	StdDev	Skew	Kurtosis	Max	Min
AFR	Malawi, South Africa, Namibia, Zimbabwe	264	0.0506	0.0615	0.0411	–0.5068	2.0920	0.1349	–0.0435
ASI	Thailand, Korea, Malaysia, Singapore, Sri Lanka	264	0.0281	0.0258	0.0172	0.2970	2.1345	0.0691	-0.0050
CHN	China	144	0.0416	0.0340	0.0281	0.2069	1.9367	0.1105	–0.0045
IND	India	86	0.0615	0.0613	0.0138	–0.0945	2.1947	0.0885	0.0313
MPC	Mexico, Morocco	34	0.0160	0.0116	0.0128	0.4843	2.0752	0.0389	–0.0048
MSA	Venezuela, Jamaica, Antilles, Honduras, Chile	264	0.0618	0.0477	0.0667	1.5358	6.9465	0.4069	–0.0245

Source: Own calculation based on IMF (2000).

Figure 2 Price-cost-ratios for different risk aversion coefficients



4. Scenarios and Results

For our central case simulations, we assume a uniform 20 % cutback requirement of carbon emissions across industrialized countries vis-à-vis the business-as-usual emission level in 2010 (see Table 1) while developing countries remain uncommitted. This setting reflects two key ideas of international climate policy: Firstly, long-term stabilization of greenhouse gas concentrations in the atmosphere at levels recommended by the International Panel on Climate Change (IPCC, 2001) requires substantial emission cutbacks compared to the business-as-usual. Secondly, international climate policy has assigned the leading role in emissions abatement to the industrialized countries who have assumed historical responsibility for the greenhouse gas problem.[13]

To provide a meaningful basis of comparison, we first investigate a set of three scenarios that reflect different degrees in where-flexibility while abstracting from risk considerations:

NTR Industrialized countries apply carbon taxes that are high enough to meet their domestic emission abatement targets (equivalently they may establish a domestic tradable permit system).

[13] The Kyoto Protocol, which has originally been drafted along these lines, has meanwhile stripped down to a symbolic policy (Böhringer, 2002) and, thus, does not provide a useful reference scenario for our analysis.

CLUB Industrialized countries can trade emission rights with each other but are not allowed to purchase project-based emission credits from developing countries.

GLOBAL There are no restrictions to where-flexibility. Beyond trading emission rights among each other, industrialized countries can buy emission credits from developing countries through abatement projects. Investment risks are neglected.

A second set of scenarios extends the specification of the *GLOBAL* scenario by alternative risk attitudes of investors towards CDM projects in developing countries:[14]

μ Investors are risk-neutral and discount emission credits purchased through CDM projects with the mean risk value of the developing country where projects are undertaken.

(μ,σ) Investors adopt the mean-variance criterion. Covering the wide range of possible Arrow-Pratt coefficients, we choose a lower bound value (α=10) to characterize a risk-averse agent and an upper bound value (α=25) to characterize a highly risk-averse agent.

VaR Investors behave according to the Value at Risk (*VaR*) criterion. Without any distributional assumption imposed, we select two alternative values for β that correspond to a confidence level of either 0.75 (i.e. $\beta = 2$) or 0.94 (i.e. $\beta = 4$).[15]

Table 3 reports the simulation results for the first set of scenarios.[16] Without emission trading (scenario *NTR*), each industrialized country has to meet its reduction target exclusively by domestic action. The associated marginal abatement costs per ton of carbon range from 55 USD for FSU up to 195 USD for CAN. Given the same relative reduction target, differences in marginal costs across countries can be traced back to cross-country differences in energy and carbon intensities, initial energy prices[17] or the ease of carbon substitution through fuel switching or energy savings as embodied in the respective marginal abatement cost curves. Compliance costs for the *NTR* case correspond to inframarginal abatement costs by taking the integral of the marginal abatement cost curve.

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14 We assume that the risks of emission trading between industrialized countries can be neglected.

15 In Figure 2 we can see that these β-values under VaR correspond to higher α-values under (μ,σ) preferences, which implies higher risk aversion.

16 Note that all of our quantitative results are readily replicable with the partial equilibrium model as captured by equations (7) – (12) and the data provided by Table 1 and Table 2.

17 For example, higher initial energy prices due to prevailing taxes require - ceteris paribus - higher carbon taxes in order to reach the same relative cutback in energy demand.

Where-flexibility through emission trading across industrialized regions (scenario *CLUB*) reduces aggregate compliance costs by roughly 15 % providing a pareto-superior solution to the *NTR* scenario.[18] Countries whose marginal abatement costs under *NTR* are below equalized abatement costs under *CLUB* export carbon rights, thereby abating more emissions domestically than are required by their specific reduction target. Likewise, countries with higher domestic marginal abatement costs will become permit importers reducing their domestic abatement burden.

Unrestricted where-flexibility under *GLOBAL* through CDM projects between the developed world and developing countries will dramatically decrease the overall compliance costs by more than 70 % vis-à-vis the *NTR* cost level and about 65 % vis-à-vis the *CLUB* level. Direct revenues to developing countries under *GLOBAL* amount to roughly 8.4 bn USD. However, these are only the incremental abatement costs from abatement measures. Including additional FDI that would not have occurred otherwise, total investment flows to developing countries may be considerably larger (Zhang and Maruyama, 2001). It becomes clear that the CDM mechanism could provide substantial financial transfers to the developing world. In total revenue terms, CDM flows under *GLOBAL*, which are purely determined by marginal abatement costs and size of mitigation possibilities, will benefit CHN by far the most, since it disposes over large low-cost abatement options.

Global marginal abatement costs drop to 32 USD per ton of carbon, which is roughly a third of the CLUB level and falls substantially short of the lowest marginal abatement cost for purely domestic action of industrialized countries (*NTR*). As a consequence, all industrialized countries turn into net importers of emission rights. In total, the domestic abatement share of the industrialized world is less than 50 % with some countries fulfilling less than 30 % of their abatement duty through domestic mitigation projects: EUR, e.g., achieves only 29.7 % of its total abatement requirement of 208 MtC (i.e. 20% of 1040 MtC) domestically.

[18] In our partial equilibrium framework, we do not capture terms-of-trade effects that could make a single country worse off (see Böhringer and Rutherford, 2002).

Table 3 Economic impacts of carbon abatement

	NTR	*CLUB*	*GLOBAL*
A. Marginal abatement costs (in USD/tC)			
AUN	74.1	98.2	32.2
CAN	194.6	98.2	32.2
EIT	56.2	98.2	32.2
EUR	169.9	98.2	32.2
FSU	54.5	98.2	32.2
JPN	195.3	98.2	32.2
USA	89.5	98.2	32.2
All others	0	0	32.2
B. Cost of compliance (in million USD)			
AUN	789	720	560
CAN	2.699	2.096	895
EIT	984	540	822
EUR	14.922	12.516	5.549
FSU	2.605	1.305	2.221
JPN	5.513	4.261	1.809
USA	13.346	13.242	8.304
AFR	0	0	-675
ASI	0	0	-804
CHN	0	0	-5.372
IND	0	0	-613
MPC	0	0	-447
MSA	0	0	-475
Total	40.858	34.680	11.775
C. Domestic abatement share (in % of total abatement requirement) [a]			
AUN	100	121.6	56.1
CAN	100	60.9	27.1
EIT	100	149.4	66.9
EUR	100	67.0	29.7
FSU	100	148.7	70.1
JPN	100	59.8	26.0
USA	100	106.7	48.8
Total [b]	100	100	45.6

[a] Values below 100 % indicate permit imports, values above 100 % indicate permit exports.
[b] With respect to total industrialized emissions in 2010.

We now turn to the implications of risk in mitigation projects in developing countries, which are summarized for the second set of scenarios in Table 4. To accommodate a convenient comparison, the results for scenario *GLOBAL* that serve as the 'no-risk' reference case are reported again. In general, the accounting of risk should result in a reduction of total cost savings from CDM projects, since risk premia increase the costs for emission credits from the investor's perspective. Consequently, domestic abatement action of industrialized countries should rise vis-à-vis the *GLOBAL* scenario. Country-specific risk premia imply non-uniform deductions from the (increased) uniform emission market price across CDM countries (see section A in Table 4). As has been pointed out in Section 3.2, low-risk countries may benefit from risk considerations at the expense of high-risk countries through both higher effective prices for carbon credits and more CDM projects compared to the case *GLOBAL*. The qualitative reasoning is confirmed by the quantitative results. With higher risk aversion, the market price for emission credits paid by industrialized countries increases and is accompanied by a decline in their cost savings from CDM projects and an increase in domestic action. As to developing countries, low-risk regions MPC and ASI fare better the more risk-averse investors become, while high-risk countries such as AFR and MSA do worse. The distribution of gains shows a similar distribution as FDI flows across developing countries (see Table 1).

However, our quantitative results suggest that the risk-induced changes are relatively small. If investors are risk-neutral, i.e. for the scenario μ, the changes are close to negligible (e.g. with respect to country-specific compliance costs changes as compared to *GLOBAL* are only as high as 3 % with total compliance costs increased by 2.4 %). When investors decide according to the mean-variance criterion, the effects compared to *GLOBAL* are still very small. Even for α=25, the largest deviation from *GLOBAL* in country-specific compliance costs is about 4 % (regions MPC and MSA). The total increase in compliance costs amounts to 3.2 %.

The implications of risk become more relevant for the *VaR* scenario. When investors go for high safety of returns, compliance costs vary between 3 % (AFR, CHN) and 11 % (MPC, MSA). Total cost of compliance will increase to 10 % above the level of the *GLOBAL* scenario. As indicated by the larger differences in marginal abatement costs, we see a substantial shift in comparative advantage from high-risk countries AFR and MSA to low-risk countries MPC and ASI. The latter benefit in particular from higher country-specific project volumes, although the total amount of emission credits across all developing countries has distinctly declined. Towards higher overall risk perception in project-based emission crediting with developing countries, the domestic abatement share of industrialized countries increases from 45.6 % to 48.7 % (*VaR*, β = 4).

Table 4 Implications of Investment Risks

	GLOBAL	μ	(μ,σ)		*VaR*	
		$\alpha = \beta = 0$	$\alpha = 10$	$\alpha = 25$	$\beta = 2$	$\beta = 4$
A. Marginal abatement costs (in USD/tC)						
AUN	32.2	33.0	33.1	33.2	34.1	35.3
CAN	32.2	33.0	33.1	33.2	34.1	35.3
EIT	32.2	33.0	33.1	33.2	34.1	35.3
EUR	32.2	33.0	33.1	33.2	34.1	35.3
FSU	32.2	33.0	33.1	33.2	34.1	35.3
JPN	32.2	33.0	33.1	33.2	34.1	35.3
USA	32.2	33.0	33.1	33.2	34.1	35.3
AFR	32.2	31.3	31.1	30.8	29.6	27.7
ASI	32.2	32.1	32.1	32.2	32.0	31.9
CHN	32.2	31.6	31.5	31.5	30.8	29.9
IND	32.2	31.0	31.0	31.1	31.1	31.2
MPC	32.2	32.4	32.5	32.6	32.7	33.0
MSA	32.2	31.0	30.2	29.1	27.5	23.7
B. Cost of compliance (in million USD)						
AUN	560	569	570	571	581	594
CAN	895	915	917	920	941	970
EIT	822	833	834	836	848	863
EUR	5.549	5.665	5.679	5.700	5.828	6.002
FSU	2.221	2.248	2.251	2.256	2.286	2.324
JPN	1.809	1.848	1.852	1.859	1.902	1.961
USA	8.304	8.451	8.468	8.494	8.653	8.867
AFR	-675	-676	-674	-672	-668	-656
ASI	-804	-821	-824	-829	-847	-876
CHN	-5.372	-5.427	-5.436	-5.451	-5.497	-5.565
IND	-613	-608	-611	-615	-631	-656
MPC	-447	-462	-464	-467	-480	-500
MSA	-475	-474	-467	-457	-451	-423
Total	11.775	12.061	12.095	12.147	12.466	12.904
C. Domestic abatement share (in % of total abatement requirement) [a]						
AUN	56.1	57.1	57.2	57.4	58.4	59.9
CAN	27.1	27.6	27.7	27.8	28.3	29.0
EIT	66.9	68.1	68.3	68.5	69.8	71.6
EUR	29.7	30.2	30.3	30.4	30.9	31.8
FSU	70.1	71.3	71.4	71.6	72.9	74.6
JPN	26.0	26.5	26.5	26.6	27.2	27.9
USA	48.8	49.7	49.8	49.9	50.9	52.1
Total [b]	45.6	46.4	46.5	46.7	47.5	48.7

[a] Values below 100 % indicate permit imports, values above 100 % indicate permit exports.
[b] With respect to total industrialized emissions in 2010.

5. Sensitivity analysis

We have performed a 'piecemeal' sensitivity analysis with respect to the abatement target for industrialized countries, thereby setting the uniform carbon reduction requirements either at 10 % or 30 %. When emission targets for the industrialized world become more (less) stringent, marginal abatement costs increase (decrease) and the total domestic abatement share decreases (increases). Where-flexibility provides higher (lower) overall cost savings, while compliance costs for industrialized countries as well as benefits from CDM for developing countries rise (diminish) towards higher (lower) targets. Our central insight on the relatively small impacts of risk consideration under risk neutrality remains robust: Unless investors are very risk-averse, changes in the magnitude of compliance costs as well as the pattern of abatement are rather negligible.

Another issue addressed by our sensitivity analysis refers to the estimation of investment risks in Section 3.3. To illustrate the sensitivity of results to risk estimates, we have run two additional sub-scenarios for *VaR* ($\beta = 4$) with a 20 % reduction target where the mean value is augmented by either a single standard deviation or double that amount. Table 5 summarizes the results. We see that shifts in the assumed default spreads cause substantial effects. Higher spreads imply substantially higher international prices for emission credits, and the differences in risk premia across developing countries become much more pronounced for risk averse investors. The implied shifts in comparative advantage for undertaking CDM projects now become dramatic for the high-risk region MSA. Only very cheap CDM projects in MSA remain competitive after risk adjustment, thereby driving down its trading volume and the associated benefits from CDM close to zero. Although the global trade in emission credits shrinks, i.e. industrialized countries undertake much more abatement domestically, low-risk countries such as MPC gain both in terms of increased credit volume as well as higher prices, since they become relatively safer (more attractive) for investors from the developed world.

Table 5 Impacts of higher risk premia

	$VaR\ (\beta = 4)$		
	$E\tau_i$	$E\tau_i + \sigma_{\tau_i}$	$E\tau_i + 2\cdot\sigma_{\tau_i}$
Marginal abatement costs (in USD/tC)			
AUN	35.3	38.9	43.7
CAN	35.3	38.9	43.7
EIT	35.3	38.9	43.7
EUR	35.3	38.9	43.7
FSU	35.3	38.9	43.7
JPN	35.3	38.9	43.7
USA	35.3	38.9	43.7
AFR	27.7	22.5	16.4
ASI	31.9	31.8	31.9
CHN	29.9	27.5	24.7
IND	31.2	31.7	32.6
MPC	33.0	33.8	35.2
MSA	23.7	13.2	0.2
Cost of compliance (in million USD)			
AUN	594	629	671
CAN	970	1.052	1.159
EIT	863	901	941
EUR	6.002	6.500	7.144
FSU	2.324	2.420	2.517
JPN	1.961	2.128	2.346
USA	8.867	9.462	10.189
AFR	-656	-610	-528
ASI	-876	-961	-1.084
CHN	-5.565	-5.733	-5.934
IND	-656	-731	-841
MPC	-500	-562	-651
MSA	-423	-310	-21
Total	12.904	14.185	15.909
Domestic abatement share (in % of total abatement requirement) [a]			
AUN	59.9	64.0	69.4
CAN	29.0	31.1	33.9
EIT	71.6	76.7	83.4
EUR	31.8	34.1	37.1
FSU	74.6	79.6	86.1
JPN	27.9	30.1	32.7
USA	52.1	55.8	60.5
Total [b]	48.7	52.1	56.6

[a] Values below 100 % indicate permit imports, values above 100 % indicate permit exports.
[b] With respect to total industrialized emissions in 2010.

6. Conclusions

We have investigated how risk considerations affect the economic implications of emission crediting. Our quantitative results show that the incorporation of country-specific investment risks induces rather small changes to the magnitude and distribution of benefits from project-based emission trading vis-à-vis a situation where investment risks are neglected.

If investors go for high safety of returns, however, there is a noticeable decline in the overall volume of emission crediting and the associated total economic benefits. Differences in risk across developing countries then become more pronounced with converse implications for high-risk and low-risk developing countries. While low-risk developing countries attract higher project volumes and benefit from higher effective prices per emission credit compared to a reference scenario without risk, the opposite applies to high-risk countries. The - politically undesired – shift in comparative advantage of emission abatement against high-risk, typically least-developed, countries may become dramatic if risk-averse investors perceive large differences in project-based risks across countries. In this case, only very cheap mitigation projects in high-risk countries will be realized, driving down the respective country's benefits from emission crediting to the advantage of low-risk developing countries. This simulated pattern of regional imbalance is confirmed by the empirical evidence for activities implemented jointly (AIJ) that have been undertaken so far under the pilot phase of the Kyoto Protocol: Of the 152 AIJ projects in 2001, 85 have been concentrated in Latin America and Caribbean, 39 in Economies in Transition, 19 in the Asia and Pacific region, and only 9 in Africa (UNFCCC, 2001).

Our simulation results indicate the importance of risk reduction measures in countries with high project risks. Such measures may include contractual agreements, financial project design, and insurance and guarantees by private and public institutions (Zhang and Maruyama, 2001; Dailamy and Leipziger, 1999). In addition, public funds, such as official development assistance and Global Environment Facility (GEF) funds, may be used to mitigate country risks associated with climate-friendly project investment and to counteract the risk-ridden shifts in mitigation projects across developing countries.

In our analysis, we have not investigated to what extent the asymmetric distribution of risks may affect global efficiency of 'where'-flexibility for alternative initial distributions of abatement duties. As with transaction costs, permit market equilibrium and aggregate compliance costs will not be independent from the initial permit allocation (Montero, 1997; Stavins, 1995). This aspect is of potential importance with respect to future (Post-Kyoto) GHG abatement policies, which may include stringent emission reduction targets for the industrialized world as well as the developing world. We plan to address this issue in future research work.

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